International Journal of Research, Science, Technology & Management
ISSN Online: 2455-2240, Volume 14 Issue III, March 2019

CONFINEMENT LOSS OPTIMIZATION WITH ENHANCE REFRACTIVE INDEX IN MICROSTRUCTURE CORE

Ramesh S. , Guru Mann

ABSTRACT

The photonic crystal fiber (PCF) is a novel single-material optical waveguide realized by an arrangement of air-holes running along the full length of the fiber. Simulated and measured results are presented in this paper for the Confinement loss for different microstructure core of photonic crystal fiber with enhance refractive index. Loss is measured for wavelength λ=1.55 μm.

INDEX TERMS- confinement loss, photonic crystal fiber, microstructure core.

1. INTRODUCTION

Growth in optical fiber gives a new class based on the properties of photonic crystals named as photonic crystal fiber (PCF). The term "photonic crystal fiber" was coined by Philip Russell in 1995-1997(he states (2003) that the idea dates to unpublished work in 1991) [1][2] , although other terms such as microstructure fiber, holey fiber are also used. Photonic crystal fibers (PCFs) are composed of central core which is surrounded by a cladding made from internal periodic capillaries. Structure of

Capillaries can be hollow (air) or solid. A defect can be imposed to the structure by removing central capillary (ies) which acts as core. Light can propagate through the defects (i.e. the core) of this crystal structure.

2. CONFINEMENT LOSS

Number of losses occurs in PCFs, such as intrinsic material absorption loss, Rayleigh scattering loss, confinement loss, and so on. Fabrication-related losses can be reduced by carefully handled during the fabrication process. Confinement loss occurs in single-material fibers [3]. As the SiO_2 materials are non absorbing, they don't have any imaginary component [4]. The guided modes are inherently leaky for PCFs that are made from pure silica because the core index is the same as the index of the outer cladding without air-holes [4].

The confinement loss can be calculated by using imaginary part of n_{eff} i.e, the effective modal index [5] as given below:

$$L_c = 8.686 * \mathrm{Im}[k_o n_{eff}] * 10^3 \text{ dB/km}$$

Where $\mathrm{Im}[n_{eff}]$ denotes the imaginary part of the effective modal index and k_o is the free space wave number.

While talking about the PCFs with finite no. of rings in PCF and confinement loss becomes an important issue. The confinement loss reduces exponentially as the number of air holes rings gets increased. Also, on increasing the air-holes diameter results in the increasing of the air filling fraction which in turn reduces the confinement loss [4].

3. BIREFRINGENCE

Birefringence property of PCF gives the measure of the polarization of light that is passing through the fiber. Birefringence characteristics may show strong wavelength dependence. PCFs with high modal birefringence as compared to conventional fibers can easily be realized, because of its higher index contrast [3]. Therefore due to higher flexibility in tuning modal birefringence, it is quite possible to design PCFs with birefringence of the order of 10^{-3} which has been reported so far [20].Birefringence can be categorized as, (i) modal birefringence and (ii) phase birefringence.

The modal birefringence B_m is given by [4]:

$$B_m(\lambda) = |n^y_{eff} - n^y_{eff}|$$

Where n^y_{eff} and n^y_{eff} are the refractive indices in y and x direction respectively.

And the Phase Birefringence B_p is given by [5]:

$$B_p(\lambda) = \frac{\lambda}{2\pi} | n^y_{eff} - n^x_{eff} |$$

In addition, the refractive index of the background silica is set as n = 1.45. As confinement losses are wavelength dependent, for the convenience of discussion, we set the wavelength at $\lambda_0 = 1.55$ µm for confinement-loss calculation. Because the effective index and birefringence of PCFs are dependent on the relative structure size in wavelength, to emphasize that the results are general ones, we express numerical results in terms of the normalized frequency $v = \omega\Lambda/(2\pi c) = \Lambda/\lambda$ for the effective index and birefringence, whereas the confinement loss is expressed through the normalized hole pitch Λ/λ0.

All the air holes are arranged in a circular section, the radius of which is defined as r_0, and we designate it as air–cladding radius. Any air hole that has a center inside the air–cladding circle is included in the computation. Such a criterion would be appropriate for the analysis of the influence of air-hole size (with the same number of air holes) on the confinement loss

According to Philip St .J. Russell, in his paper titled" Photonic-Crystal Fibers (journal of light wave technology, vol. 24, no. 12, December 2006).The photonic-crystal cladding in a realistic PCF is, of course, finite in extent. For a guided mode, the Bloch waves in the cladding are evanescent, just like the evanescent plane waves in the cladding of a conventional fiber.

If the cladding is not thick enough, the evanescent field amplitudes at the cladding/coating boundary can be substantial, causing attenuation. In the solid core case for small values of d/Λ, the resulting loss can be large unless a sufficiently large number of periods are used Very similar losses are observed in hollow-core fibers, where the "strength" of the PBG (closely related to its width in β) determines how many periods are needed to reduce confinement loss to acceptable levels. Numerical modeling is useful for giving an indication of how many periods are needed to reach a required loss level. The cladding field intensity in the ultra-low loss PCF reported in falls by 9 dB per period, reaching −63 dB at the edge of the photonic-crystal region.

4. PROPOSED DESIGN

Proposed design with inserting a microstructure RLPCF core into the Hexagonal air hole PCF to have high birefringence and better confinement with improved mode area:

DESIGN PARAMETERS

Hexagonal PCF parameters are:

- vertical pitch (Λ) = 2.3 μm
- Air hole diameter to pitch ratio = 0.6
- Number of rings = 4
- Silica as base material

PARAMETERS OF MICROSTRUCTURE CORE:

There are three different variations in the microstructure core-

- Vertical pitch is 1/10th of hexagonal design pitch

- Vertical pitch is 1/5th of hexagonal design pitch
- Vertical pitch is 1/20th of hexagonal design pitch

1/5th dimensions

Horizontal to vertical pitch ratio=0.6, $2r/\Lambda' = 0.2$, Radius of air hole = 0.04

$\Lambda' = 2.3/5 = 0.46$, b= 0.276

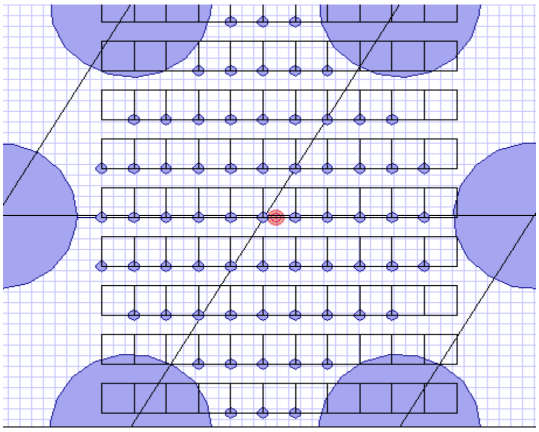

Figure 1: Micro-structured Core of the proposed design with silica as base material

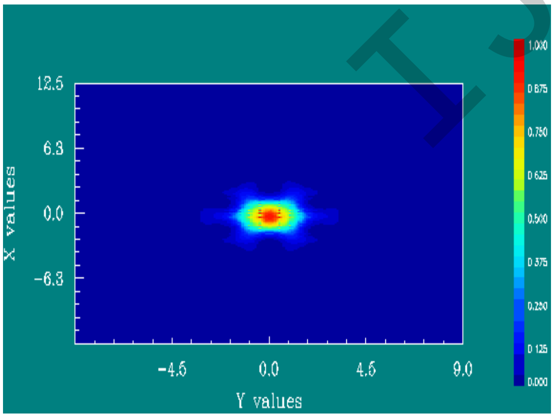

Figure 2: Field Intensity Distribution at 1.55μm (X Polarized)

Design with taking a different core material (n = 1.56) in the micro structured core

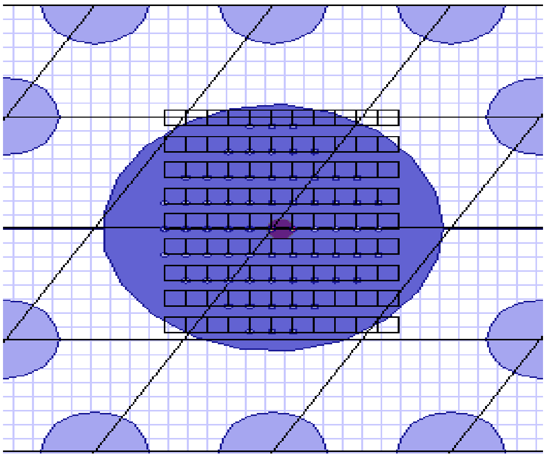

Figure 3: Micro-structured Core of the proposed design with enhance refractive index

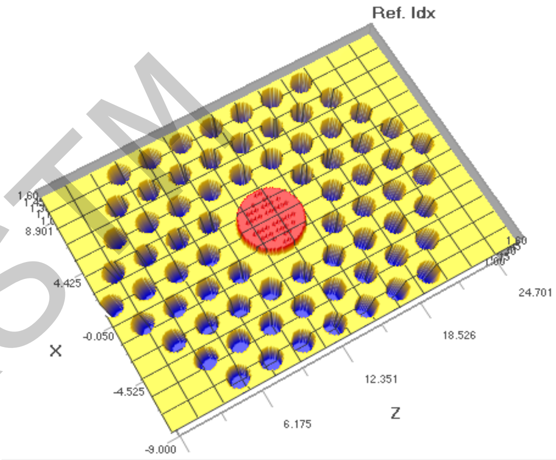

Figure 4: Micro-structured core with enhanced index Refractive index distribution

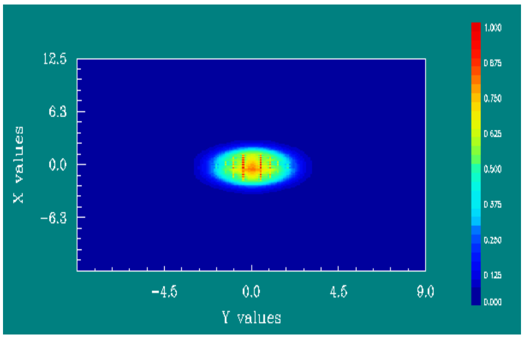

Figure 5: Field Intensity Distribution at 1.55μm (Y Polarized)

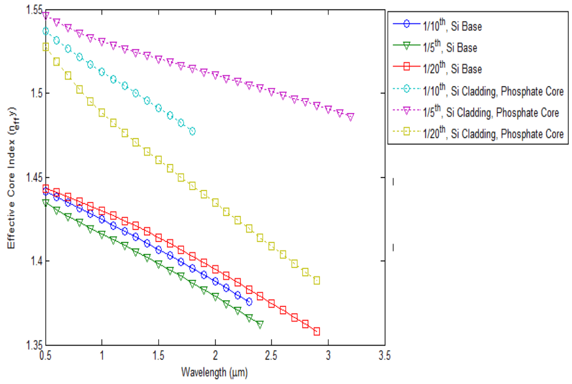

Figure 6: Effective core index as a function of wavelength for the designs with different base material in their core (Y Polarization)

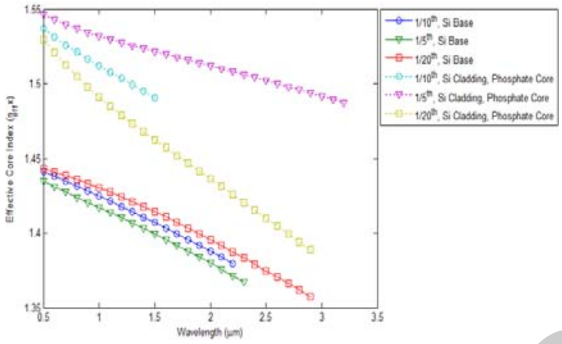

Figure 7: Effective core index as a function of wavelength for the designs with different base material in their core (X Polarization)

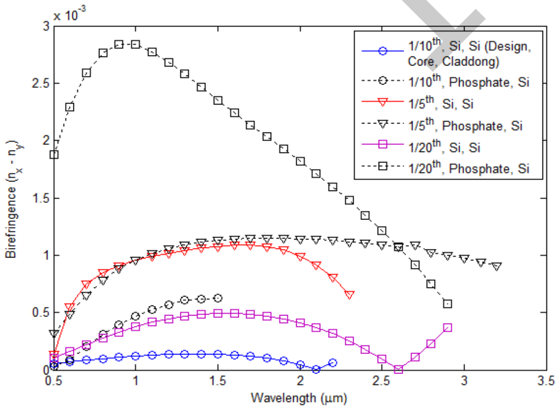

Figure 8: Graph between confinement loss and wavelength for different base material in the core

5. CONFINEMENT LOSS (CL)

All the designs offer quite low value of confinement loss (less than or equal to the order of 10^{-4}) at the wavelength of 1.55µm. Design with 1/5th parameter, enhanced core offers lowest CL among all designs.

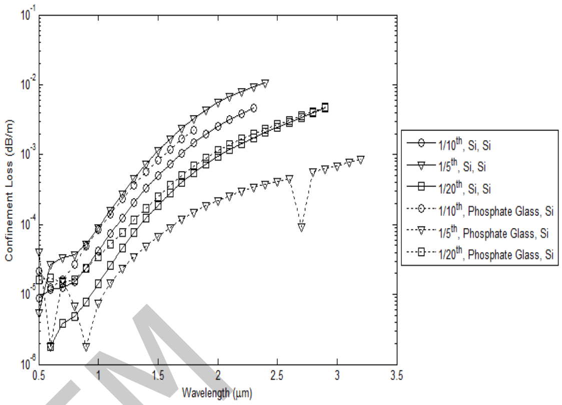

Figure 9: Graph between confinement loss and wavelength for different base material in the core

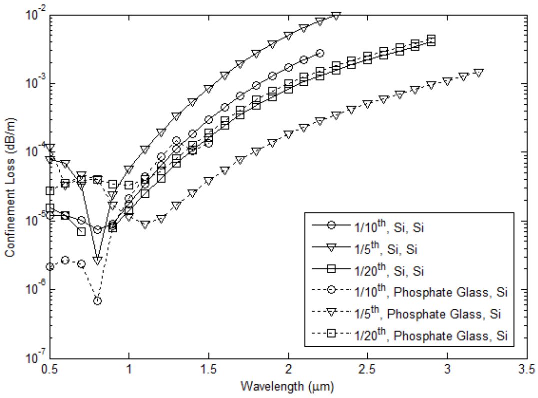

Figure 10: Graph between confinement loss and wavelength for different base material in the core(x polarization)

6. CONCLUSION

In this paper I set out to explore, **"optimization of confinement losses for different lattice structure in pcf"** to optimize the confinement loss by inserting a microstructure RLPCF core into the Hexagonal air hole PCF with different dimensions of RLPCF. I concluded that All the designs offer quite low value of confinement loss (less than or equal to the order of 10^{-4}) at the wavelength of 1.55µm. Design with 1/5th parameter, enhanced core offers lowest CL among all designs. 1/5th parameter, means Vertical pitch is 1/5th of hexagonal design pitch.

REFERENCES

[1] P. St. J. Russell, "Photonic crystal fibers", Science, vol. 299, pp.358-362, 2003 [2] G.P. Agrawal, Nonlinear Fiber Optics (Academic Press, San Diego, 2001).

[3] Saitoh K. and Koshiba M., "Numerical modeling of photonic crystal fibers," Lightwave Technology, Vol. 23, No. 11, pp. 3580-3590, 2005.

[4] M. Pourmahyabadi and Sh. Mohammad Nejad "Iranian Journal of Electrical & Electronic Engineering", Vol. 5, No. 3, pp. 170-180, 2009.

[5] Zhang fanf-di, XU Zheng-kai and Ye Pei-da, "Design of low confinement loss and highly birefringent index guiding photonic crystal fibers", Int. journal of optoelectronics Letters, Vol. 4, No 3, pp. 188-193, May 2008

[6]www.fiberoptics4scale.com/worpressfiber-dispersion-and-optical-an-overview